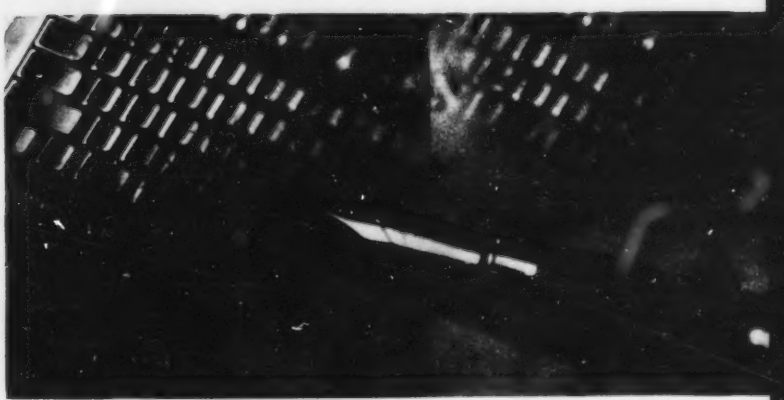
RESEARCH REPORT

DEVELOPMENT OF GENERIC ENGINEERED DETAILS FOR THE CONSTRUCTION OF RESIDENTIAL TALL WALLS



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DEVELOPMENT OF GENERIC ENGINEERED DETAILS FOR THE CONSTRUCTION OF RESIDENTIAL TALL WALLS

FOR REFERENCE ONLY
POUR RÉFÉRENCE SEULEMENT

Prepared by

Campbell Woodall & Associates Consulting Engineers Ltd.

PART IX REPORT
RAPPORT PARTIE IX

March 1999

CMHC Project Manager: Darrel R. Smith

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Purpose

Part 9 of the 1997 Alberta Building Code contains construction requirements for exterior loadbearing residential walls up to 11.8 feet (3.6m) in height. This work investigated and determined the structural requirements for building exterior loadbearing walls of single family dwellings greater in height than 11.8 feet, to a limit of 20 feet (6.1m).

The primary objective of the work was to prepare generic details, certified by a qualified structural engineer registered in Alberta, which can be utilized by competent builders to select construction requirements for walls required to be higher than the limits presently included in Part 9 of the Alberta Building Code.

Acknowledgments

The authors would like to thank the members of the Alberta Housing Industry Technical Committee for their direction and comments during the various phases of the project.

The Alberta Housing Industry Technical Committee extends its appreciation to Canada Mortgage and Housing Corporation for financial assistance with the project. Particular thanks are extended to Mr. Darrell Smith, Project Manager for CMHC, for his input throughout the project.

Executive Summary

Part 9 of the Alberta Building Code (1997) defines maximum allowable heights for exterior loadbearing walls based on their physical characteristics and the loads they support. The code, however, only specifies requirements for walls up to approximately 12 feet in height. Walls exceeding that height must be individually engineered. Significant time and expense could be saved through the availability of generic, engineered data which would allow builders in Alberta to select appropriate material and installation configurations for the tall wall requirements incorporated in their various projects. The purpose of this project was to develop such data.

Several general configurations were identified for analysis. These configurations included both solid walls and walls with varying window layouts. The range of wall dimensions was 7 to 16 feet in width by 10 to 20 feet in height. Some appurtenant components generally thought to provide additional support for tall walls were also included in the analysis. These included horizontal feature shelves, fireplaces located in corners and intra-span, interior partitions, and hip roofs.

Developmental work followed generally accepted principles of limit states design. Load carrying capacity and lateral deflection were defined as the governing limit states. The general design philosophy encompassed examination and classification of live loads throughout the province, and development of tables that link the load classification at a particular location to allowable tall wall characteristics for that location.

Two types of tall wall tables were developed. The first case – tables which identify the maximum widths of loadbearing walls of given height – was chosen as a means of addressing the option to construct tall walls in two vertical lifts. The second case – tables that identify the maximum height to which a loadbearing wall may be built – addresses the option of building tall walls with full height stud members. In the first case, stress and deflection due to wind loads constituted the governing conditions. Allowable deflection was set at 1/180 of the width of the wall. In the second case, the combination of axial loading and bending moments caused by wind loading was considered, and either stresses or deflections governed the allowable height of the wall, depending on load combination.

The structural contributions of the appurtenant components studied were found to be minimal. From the generic perspective, whatever contributions could be afforded by these items would be lost to design allowances that would have to be made to compensate for the large number of variables associated with their installation. These variables include vertical and horizontal positions on the wall, materials used, and fastening methods used. Details describing these items would have to be intricate and the potential for another field variable – misapplication of intended specifications – would likely be introduced.

The tables developed within the scope of this project allow extension of the existing limits of the Alberta Building Code, 1997 edition. Table 9.23.10.1 of the code allows walls up to approximately 12 feet in height to be built without professional design input. Properly utilized, these tables allow the construction of walls up to approximately 25 feet in height (dependent upon load conditions) to be built in Alberta without professional design input. Some situations will exist where the tables do not address the requirements of a particular project or a particular project cannot comply with the conditions accompanying the use of the tables, and in these circumstances, individual professional design will remain a requirement.

Sommaire

La partie 9 du code du bâtiment de l'Alberta (1997) définit les hauteurs maximums autorisées pour les murs porteurs extérieurs d'après leurs caractéristiques physiques et leurs charges. Le code, toutefois, prescrit seulement des exigences pour les murs allant jusqu'à environ 12 pieds de hauteur. Les murs plus hauts doivent être construits individuellement. Beaucoup de temps et d'argent pourraient être épargnés si des données techniques génériques étaient mises à la disposition des constructeurs en Alberta afin qu'ils puissent sélectionner les matériaux et les configurations d'installation appropriés pour les murs très hauts. Ce projet avait pour but d'élaborer ces données.

Plusieurs configurations générales ont été identifiées pour fins d'analyse. Elles comprenaient des murs massifs et des murs percés de fenêtres à différentes positions. Les dimensions des murs variaient de 7 à 16 pieds de largeur sur 10 à 20 pieds de hauteur. Plusieurs composants accessoires généralement considérés comme assurant un soutien supplémentaire aux murs hauts ont été inclus dans l'analyse. Il s'agissait de tablettes horizontales décoratives, de foyers en coin, de cloisons intra-portée et de toits en croupe.

Les travaux d'élaboration étaient conformes aux principes généralement acceptés pour le calcul aux états limites. La capacité de charge et la déflexion latérale ont été défini comme les états limites. La méthodologie générale consistait à faire l'examen et le classement des surcharges dans l'ensemble de la province, puis de réaliser des tableaux établissant un lien entre la catégorie de charge dans un lieu en particulier et les caractéristiques permises pour les murs élevés pour cet emplacement.

Deux types de tableaux ont été créés pour les murs élevés. Dans le premier cas - tableaux indiquant les largeurs maximums des murs porteurs d'une certaine hauteur - l'objet était de faire état de l'option de construire des murs hauts en deux montées verticales. Dans le second - tableaux indiquant la hauteur maximum d'un mur porteur - concerne l'option de construire des murs élevés au moyen de poteaux pleine hauteur. Dans le premier cas, l'effort et la déflexion dus aux charges du vent constituaient les conditions retenues. La déflexion admissible a été fixée à 1/180^{e} de la largeur du mur. Dans le deuxième cas, la conjugaison de la charge axiale et des moments de flexion causés par le vent a été prise en considération, et les efforts ou déflexions dictaient la hauteur permises du mur, selon la combinaison des charges.

Il s'est avéré que l'apport structural des composants accessoires est minime. Dans une optique générale, tout apport éventuel de ces composants serait perdu à cause des modifications de calcul qui seraient nécessaires pour compenser le grand nombre de variables associées à leur installation. Ces variables sont les positions verticale et horizontale sur le mur, les matériaux utilisés et les méthodes de fixation employées. Les détails y afférents seraient compliqués et une nouvelle variable C spécification mal interprétée en chantier C serait probablement introduite.

Les tableaux établis dans le cadre de ce projet permettent de repousser les limites actuelles du code du bâtiment de l'Albert (édition de 1997). Le tableau 9.23.10.1 du Code prévoit la construction de murs jusqu'à environ 12 pieds de hauteur sans l'intervention d'un concepteur

professionnel. S'ils sont bien utilisés, les tableaux permettent de construire des murs jusqu'à environ 25 pieds de hauteur (selon les conditions de charge) en Alberta sans l'intervention d'un concepteur professionnel. Comme il surviendra des situations où les tableaux ne répondent pas aux exigences d'un projet ou un projet ne peut être conforme aux conditions prévues dans les tableaux, il faudra encore consulter un concepteur professionnel.

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1 Introduction

Over the past several years, single detached homes featuring "great rooms" and other spaces partly enclosed by exterior walls greater in height than one storey (tall walls) have become increasingly popular among consumers in Alberta. These exterior loadbearing walls can be as high as 20 feet, and their features can include various configurations of window and door openings, and interior appurtenances and attachments such as fireplaces, adjacent stairs, and decorative ledges.

Part 9 of the Alberta Building Code (1997), which governs house construction, defines maximum allowable heights for exterior loadbearing walls in terms of their stud sizes and spacing. The Code, however, only provides requirements for walls up to approximately 12 feet in height. When walls exceeding that height are to be built, each must be individually engineered. That is, to meet the requirements of the Code, builders must retain professional engineers to prepare structural designs for the tall walls. This naturally adds to the price of the home, and can adversely affect the construction schedule.

A significant number of all two-storey homes built in Alberta each year contain at least one tall wall not covered by the present Code. Significant time and expense could be saved through the availability of generic, engineered data which would allow builders to select appropriate material and installation configurations for the tall wall requirements incorporated in their various projects. The purpose of this project was to develop such data.

2 Objective

The primary objective of the work was to develop, in a form suitable for review and acceptance by the authority having jurisdiction over the Alberta Building Code, a set of engineered data designed to allow builders to identify and specify structurally appropriate criteria for the construction of tall walls in various configurations, without the necessity of retaining engineering services.

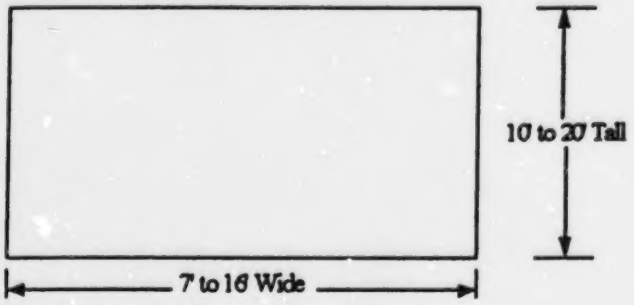
3 Scope of the Work

3.1 Wall Configurations

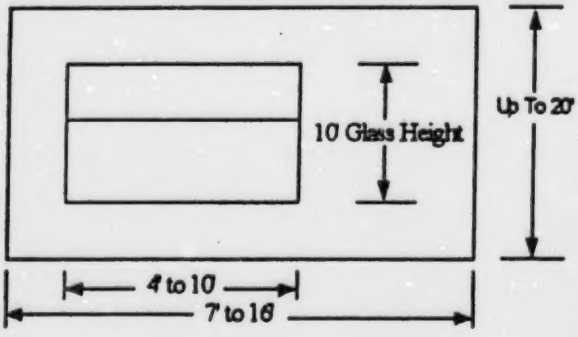
To cover the range of popular choices noted by builders, several general configurations were identified for analysis. They are:

- A solid wall, containing no openings;
- A wall containing two sets of windows. The windows are to be stacked in the upper wall section with no header in between, and the maximum glass height is 10 feet.
- A wall containing two sets of windows. The windows are to be stacked in the upper wall section and separated by a header, and the maximum glass height is 10 feet.
- A wall containing three sets of windows. The windows are to be stacked with no headers between, and the total glass height is 14 feet.
- A wall containing three sets of windows. The windows are to be stacked and separated by headers and framing above and below. The total glass height is 14 feet.

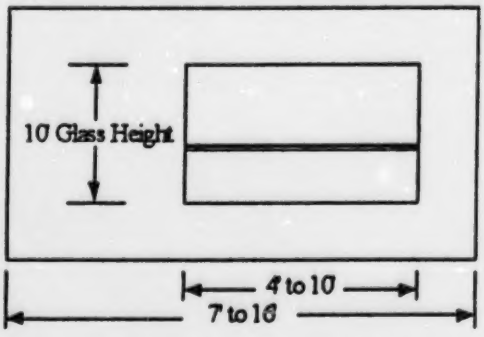
The range of wall dimensions is 7 to 16 feet in width by 10 to 20 feet in height, and is common to each configuration. Window rough opening widths considered are 48", 56", 72", 84", 96" and 120". These rough opening widths are common to each configuration containing windows. The chosen configurations are represented graphically by Figure 1.



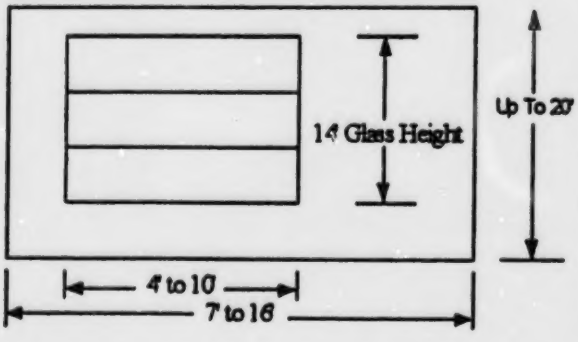
(a) Straight Wall, No Windows



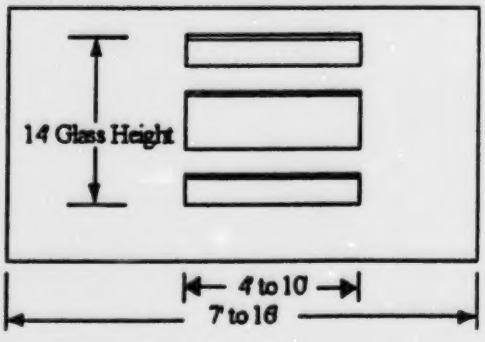
(b) Two Sets of Windows, Stacked, No Header



(c) Two Sets of Windows, Stacked, Separated by Header



(d) Three Sets of Windows, Stacked, No Header



(e) Three Sets of Windows, Stacked, Separated by Headers and Framing

Figure 1 - Tall Wall Configurations

3.2 Wall Appurtenances

Several components are presently used to provide additional support for tall walls. Some also serve decorative and aesthetic functions. Those that were considered within the scope of this work include horizontal feature shelves (or ledges), fireplaces (located in corners and intra-span), interior partitions, and hip roofs.

4 Code Considerations

Housing and small buildings are governed by Part 9 of the Code. Section 9.23 governs wood-framed construction where the spacing of members does not exceed 16" and the design live load does not exceed (approximately) 50 lb./sq.ft.

Subsection 9.23.10 applies to wall studs. Other sections and subsections that contain requirements relevant to the analysis of tall walls are:

- 9.3.2 Lumber and Wood Products – in this subsection, the grade of lumber required for wall framing is specified as NLGA Stud grade. Lumber species can be spruce, pine, fir or northern species.
- 9.4 Structural Requirements – requirements for design, and reference to Part 4 for design of components and systems where required.
- 9.23.3 Fasteners – the minimum requirements for nailing of stud wall components are specified.
- 9.23.5 Notching and Drilling – limitations are placed on the extent of cutting that can be done on or within framing members.
- 9.23.11 Wall Plates – minimum specifications for wall plates are laid out.
- 9.23.12 Framing Over Openings – minimum requirements for lintels are specified.
- 9.23.16 Wall Sheathing – minimum requirements for exterior wall sheathing are specified.

Operationally, Article 9.23.10.1 of the Code governs allowable heights of loadbearing exterior walls. This article references Table 9.23.10.1, which allows a maximum unsupported height in the range of 5.904 ft. to 11.808 ft. (1.8m to 3.6m), depending upon various supported load, stud size and stud spacing conditions.

From the Code perspective, therefore, the work addresses the subsections of Part 9 dealing with wood stud wall construction, and focuses on Table 9.23.10.1. More specifically, the work focuses on defining the conditions that must be met to enable extension of the range of allowable unsupported heights of exterior loadbearing walls from the limits of Table 9.23.10.1 to 20 feet.

5 Methods

Structural design work was carried out in accordance with:

- the design requirements contained in Part 4 of the Alberta Building Code, 1997 (as required by Part 9),
- the guidelines contained in Chapter 4 of the Supplement to the National Building Code, 1995, Commentary on Part 4,
- the methods described in CAN/CSA-086.1-94, Engineering Design in Wood (Limit States Design), and
- the consultant's expertise and experience.

Developmental work followed generally accepted principles of limit states design. For this work, load carrying capacity and lateral deflection were selected as the governing limit states. Load carrying capacity ensures that occupant safety aspects are addressed, and deflection considerations address the serviceability aspect. Both of these properties can be derived using loading data published in current codes and lumber characteristics tables.

The general design philosophy encompassed examination and classification of live loads throughout the province, and development of tables that link the load classification at a particular location to allowable tall wall characteristics for that location. These approaches respond to the requirements that the data developed be generic in nature, and that solutions to tall wall situations be easily extracted by industry practitioners with little or no structural design expertise[1].

Two types of tall wall tables were developed. The first case (tables which identify the maximum widths of loadbearing walls of given height) was chosen as a means of addressing the option to construct tall walls in two vertical lifts. For instance, a 16-foot high 2x6 wall could be built using two lifts of 8-foot studs with an intermediate plate in between. The plate is sized from stress and deflection limits due to wind loads only. The deflection criterion established for this work was 1/180 of the width of the wall. Beyond a certain width, deflections caused by loads established for the region will exceed the 1/180 limit criterion, and the maximum wall width is thereby established. The second case (tables that identify the maximum height to which a loadbearing wall may be built) addresses the option of building tall walls with full height stud members. In this case, the combination of axial loading (snow load plus dead load) and bending moments caused by wind loading is considered, and either stresses or deflections will govern the allowable height of the wall, depending on the load combination.

It is possible that solutions to tall wall configurations may exist under both of the noted construction methods. For instance, the 16-foot wall referenced above may also be built with full-length 16-foot studs. The builder can make his choice depending on cost, preference, material availability, or other factors considered to be of importance.

Framing lumber was considered to be SPF#2 or better for this work. Imperfections allowed in lesser grades have a much more compromising effect on tall walls than on regular height (8 ft.) walls.

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[1] While structural design expertise is not required to interpret the data, it is of course assumed that practitioners are familiar with the requirements of applicable codes, and with wood frame construction techniques and materials.

6 Results

The results of the work are in the form of tables, from which competent building practitioners can select appropriate construction details for specific tall wall requirements. The tables apply to wall heights beyond the range of heights presently covered in Alberta Building Code 1997, Subsection 9.23.10.

The tables are presented on the following ten pages. It must be noted that the tables in this form, though complete, are presented for illustrative purposes only. They are not to be used for construction, since they cannot serve that purpose until appropriate rulings have been issued by Alberta Labour. To that end, a complete set of the tables, bearing the engineer's stamp and seal, have been provided to the AHITC for submission under separate cover to the Alberta code authorities.

Appendix 1 presents a set of examples illustrating the use of the tables. Appendix 2 contains a derivation illustrating the engineering design methods used to develop the tables.

6.1 Load Classifications

Appendix C to the Alberta Building Code lists snow and wind loads for numerous centres in the province. Determination of tall wall properties would normally require a calculation for each location in the province, using the live loads detailed for the location. To ease calculations and reduce the sheer number of resultant tall wall height (and width) tables that would otherwise be required for generic application within Alberta, the ranges of snow and wind loads in Appendix C were divided into 3 categories – Low, Medium, and High. In the case of snow loading, a fourth group, Very High, was added to reflect the high snowfall in the Lake Louise area. Wind load categories were developed on the basis of the 1-in-30 year values. The live load categories were assigned the following limits:

Low Snow = 1.0 to 1.3 kPa

Medium Snow = 1.4 to 1.9 kPa

High Snow = 2.0 to 3.3 kPa

Very High Snow = 3.4 to 6.3 kPa[2]

Low Wind = 0 to 0.46 kPa

Medium Wind = 0.47 to 0.69 kPa

High Wind = 0.70 to 0.93 kPa.

[2] The 1997 Alberta Building Code specifies 4.1 as the ground snow load for Lake Louise. The 1990 Alberta Building Code assigned 6.3 kPa to Lake Louise. The 1990 value is used here in setting the upper limit and in performing related calculations, because it is deemed more realistic than the 1997 value.

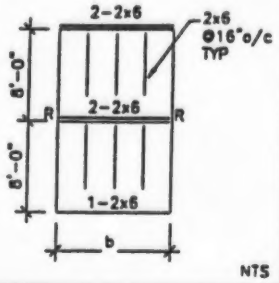
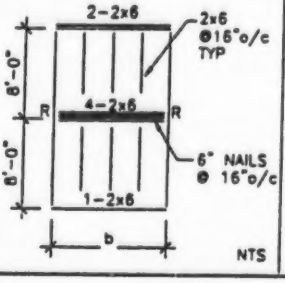
TABLE 1—DESIGN LOADS FOR LOCATIONS IN ALBERTA

		LOADS IN KPa 1/30 OCCURRENCE	LOCATION
SNOW LOAD	VERY HIGH	Ss=6.3 Sr=0.3	LAKE LOUISE
	HIGH	Ss=3.3 Sr=0.1	JASPER, BANFF, CANMORE
	MEDIUM	Ss=1.9 Sr=0.1	EDMONTON, RED DEER, PINCHER CREEK FORT McMURRAY, CARDSTON
	LOW	Ss=1.3 Sr=0.1	CALGARY, LETHBRIDGE, BROOKS TURNER VALLEY, VULCAN
WIND LOAD	HIGH	q30=0.93	PINCHER CREEK, CARDSTON, LETHBRIDGE
	MEDIUM	q30=0.69	TURNER VALLEY, BROOKS, VULCAN
	LOW	q30=0.46	CALGARY, EDMONTON, FORT McMURRAY, RED DEER, BANFF, CANMORE, JASPER

NOTE:
FOR LOCATIONS NOT LISTED ABOVE, SELECT THE APPROPRIATE WIND & SNOW LOADS FROM THE ALBERTA BUILDING CODE, 1997, APPENDIX C.

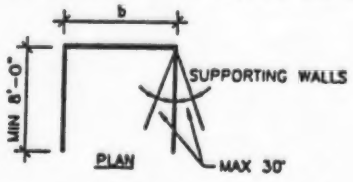
Ss=GROUND SNOW LOADS. LOAD ON ROOF TAKEN AS 0.8xSs.
Sr=DESIGN RAIN LOAD.
q30=ONE IN THIRTY YEAR WIND PRESSURE.

TABLE 2A– MAXIMUM WALL WIDTHS FOR UP TO 16'–0" HIGH LOADBEARING WALLS WITHOUT OPENINGS

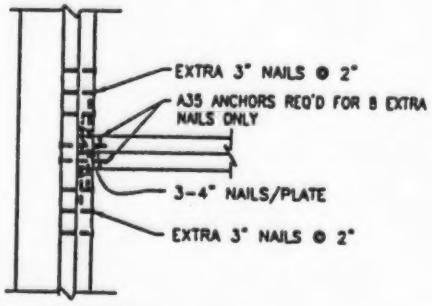
	HIGH WIND	MEDIUM WIND	LOW WIND	LAKE LOUISE–VERY HIGH SNOW, LOW WIND
 NTS	b≤10'–3" (3124mm) R= 3.47kN EXTRA NAILS 8 2–A35 FRAMING ANCHORS OR EQUAL	b≤12'–0" (3658mm) R= 3.08kN EXTRA NAILS 6 ——	b≤13'–7" (4140mm) R= 2.20kN EXTRA NAILS 4 ——	b≤12'–8" (3861mm) R= 2.10kN EXTRA NAILS 4 ——
 NTS	b≤14'–0" (4267mm) R= 4.80kN EXTRA NAILS 8 2–A35 FRAMING ANCHORS OR EQUAL	b≤15'–2" (4623mm) R= 4.50kN EXTRA NAILS 6 ——	b≤17'–1" (5207mm) R= 2.90kN —— ——	b≤16'–0" (4877mm) R= 2.70kN —— ——

NOTES:

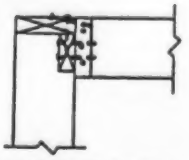
1. THE WALL MAY TAKE UP TO 18'–0" ROOF LOAD TRIBUTARY ANYWHERE IN ALBERTA.
2. WALLS FRAMED AS SHOWN ARE TO BE LATERALLY SUPPORTED AT EACH END BY FULL HEIGHT WALLS AT LEAST 8'–0" LONG, AS DETAILED BELOW.
3. R=HORIZONTAL LOADS IN KILONEWTONS (SERVICE).
4. EXTRA NAILS (3 1/2") PUT 50% ABOVE & 50% BELOW PLATE.

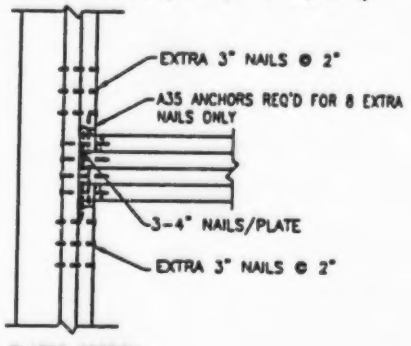


PLAN



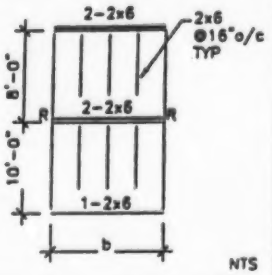
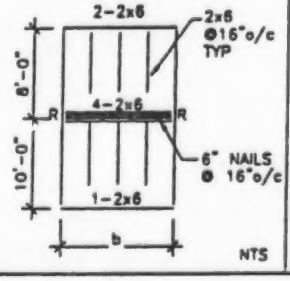
2 PLATES SECTION


PLAN CORNER NAILING PATTERN @ PLATES (3–3 1/2" NAILS/PLATE)



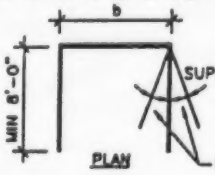
4 PLATES SECTION

TABLE 2B– MAXIMUM WALL WIDTHS FOR UP TO 18'–0" HIGH LOADBEARING WALLS WITHOUT OPENINGS

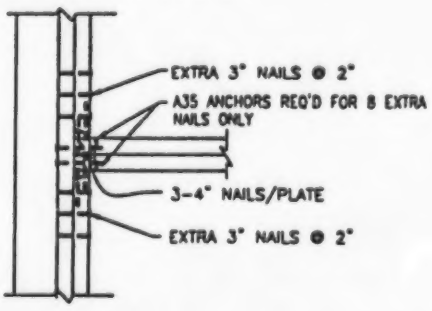
	HIGH WIND	MEDIUM WIND	LOW WIND	LAKE LOUISE–VERY HIGH SNOW, LOW WIND
 NTS	b≤9'–8" (2946mm) R= 3.80kN EXTRA NAILS 8 2–A35 FRAMING ANCHORS OR EQUAL	b≤11'–3" (3429mm) R= 3.30kN EXTRA NAILS 8 2–A35 FRAMING ANCHORS OR EQUAL	b≤13'–0" (3962mm) R= 2.50kN EXTRA NAILS 4 ——	b≤12'–6" (3810mm) R= 2.40kN EXTRA NAILS 4 ——
 NTS	b≤13'–5" (4089mm) R= 5.20kN EXTRA NAILS 8 2–A35 FRAMING ANCHORS OR EQUAL	b≤14'–8" (4470mm) R= 4.20kN EXTRA NAILS 6 ——	b≤16'–6" (5029mm) R= 3.20kN EXTRA NAILS NIL ——	b≤15–8" (4775mm) R= 3.00kN EXTRA NAILS NIL ——

NOTES:

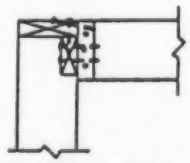
1. THE WALL MAY TAKE UP TO 18'–0" ROOF LOAD TRIBUTARY ANYWHERE IN ALBERTA.
2. WALLS FRAMED AS SHOWN ARE TO BE LATERALLY SUPPORTED AT EACH END BY FULL HEIGHT WALLS @ LEAST 8'–0" LONG. AS DETAILED BELOW.
3. R=HORIZONTAL LOADS IN KILONEWTONS (SERVICE).
4. EXTRA NAILS (3 1/2") PUT 50% ABOVE & 50% BELOW PLATE.
5. THE 8'–0" & 10'–0" LIFTS ARE INTERCHANGEABLE.

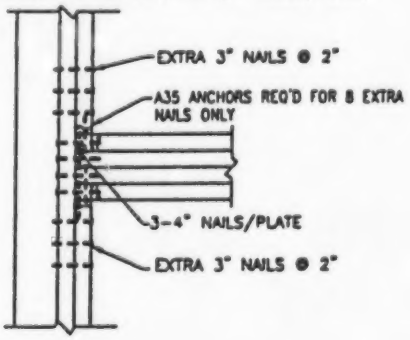


PLAN



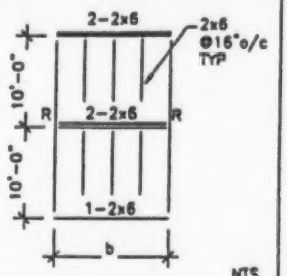
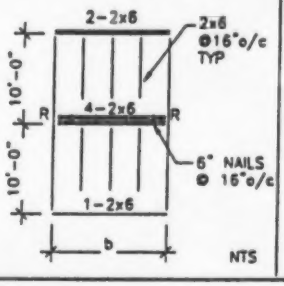
2 PLATES SECTION


PLAN CORNER NAILING PATTERN @ PLATES (3–3 1/2" NAILS/PLATE)



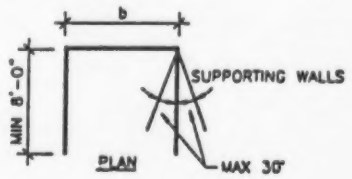
4 PLATES SECTION

TABLE 2C– MAXIMIUM WALL WIDTHS FOR UP TO 20'–0" HIGH LOADBEARING WALLS WITHOUT OPENINGS

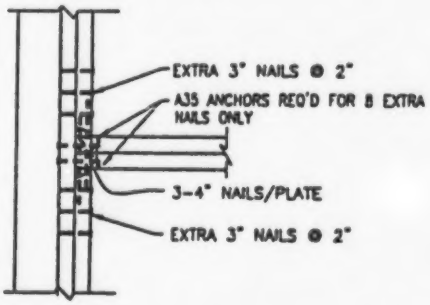
	HIGH WIND	MEDIUM WIND	LOW WIND	LAKE LOUISE–VERY HIGH SNOW, LOW WIND
 NTS	b≤9'–2" (2794mm) R= 3.90kN EXTRA NAILS 10 2–A35 FRAMING ANCHORS	b≤10'–8" (3251mm) R= 3.40kN EXTRA NAILS 8 ——	b≤12'–4" (3759mm) R= 2.60kN EXTRA NAILS 4 ——	b≤12'–3" (3734mm) R= 2.60kN EXTRA NAILS 4 ——
 NTS	b≤12'–10" (3912mm) R= 5.60kN EXTRA NAILS 10 2–A35 FRAMING ANCHORS	b≤14'–1" (4293mm) R= 4.50kN EXTRA NAILS 6 ——	b≤15'–11" (4851mm) R= 3.40kN EXTRA NAILS 2 ——	b≤15–4" (4674mm) R= 3.20kN EXTRA NAILS NIL ——

NOTES:

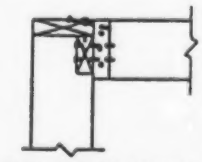
1. THE WALL MAY TAKE UP TO 18'–0" ROOF LOAD TRIBUTARY ANYWHERE IN ALBERTA.
2. WALLS FRAMED AS SHOWN ARE TO BE LATERALLY SUPPORTED AT EACH END BY FULL HEIGHT WALLS @ LEAST 8'–0" LONG. AS DETAILED BELOW.
3. R=HORIZONTAL LOADS IN KILONEWTONS (SERVICE).
4. EXTRA NAILS (3 1/2") PUT 50% ABOVE & 50% BELOW PLATE.

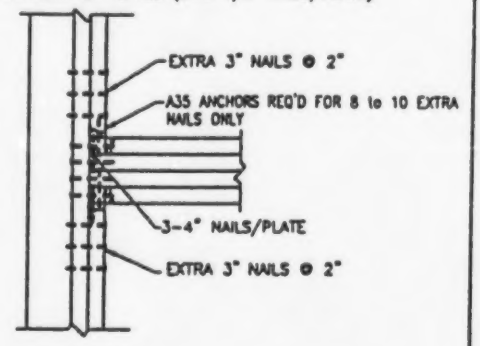


PLAN



2 PLATES SECTION

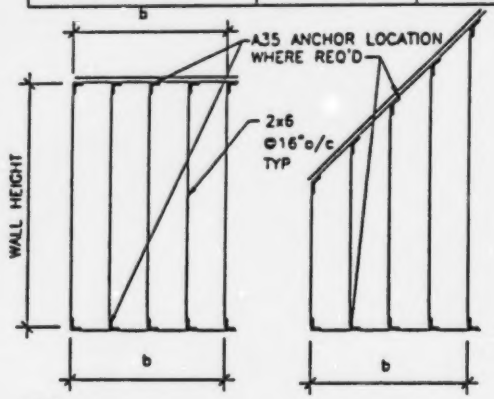

PLAN CORNER NAILING PATTERN @ PLATES (3–3 1/2" NAILS/PLATE)



4 PLATES SECTION

TABLE 3A– MAXIMUM WALL HEIGHT FOR LOADBEARING WALLS WITHOUT OPENINGS–2x6 @ 16"o/c FULL HEIGHT STUDS

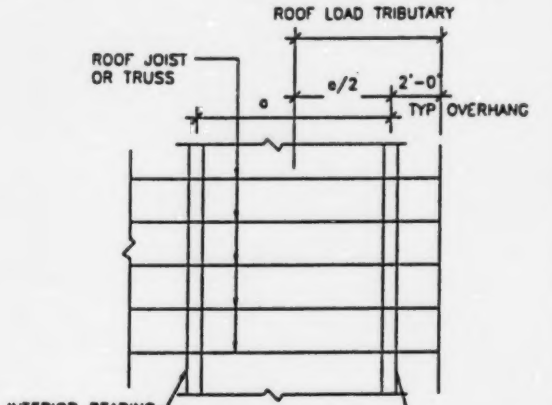
WIND LOAD	SNOW LOAD	ROOF LOAD TRIBUTARY (o/2 + OVERHANG)				
		0 to 4'-0"	8'-0"	12'-0"	15'-0"	18'-0"
		WALL HEIGHT				
HIGH 3 NAILS PER STUD +1 A35 FRAMING ANCHOR	HIGH	15'-7" (4750mm)	14'-10" (4521mm)	14'-8" (4470mm)	14'-5" (4394mm)	14'-1" (4293mm)
	MEDIUM	15'-8" (4775mm)	15'-5" (4699mm)	14'-10" (4521mm)	14'-10" (4521mm)	14'-8" (4470mm)
	LOW	15'-8" (4775mm)	15'-6" (4724mm)	15'-3" (4648mm)	14'-10" (4521mm)	14'-9" (4496mm)
MEDIUM 3 NAILS PER STUD	HIGH	16'-10" (5131mm)	16'-3" (4953mm)	15'-10" (4826mm)	15'-3" (4648mm)	14'-6" (4420mm)
	MEDIUM	17'-0" (5182mm)	16'-9" (5105mm)	16'-3" (4953mm)	16'-1" (4902mm)	15'-10" (4826mm)
	LOW	17'-0" (5182mm)	16'-9" (5105mm)	16'-6" (5029mm)	16'-3" (4953mm)	16'-1" (4902mm)
LOW 3 NAILS PER STUD	HIGH	18'-10" (5740mm)	18'-2" (5537mm)	17'-6" (5334mm)	16'-6" (5029mm)	15'-5" (4699mm)
	MEDIUM	19'-0" (5791mm)	18'-7" (5664mm)	18'-2" (5537mm)	17'-9" (5410mm)	17'-6" (5334mm)
	LOW	19'-3" (5867mm)	18'-9" (5715mm)	18'-5" (5613mm)	18'-2" (5537mm)	17'-9" (5410mm)
LAKE LOUISE 3 NAILS PER PLATE	VERY HIGH	18'-6" (5639mm)	16'-10" (5131mm)	14'-10" (4521mm)	13'-9" (4191mm)	12'-6" (3810mm)



NOTE:
b IS UNLIMITED

WALL ELEVATION
NTS

WALL ELEVATION
(SLOPED ROOF)

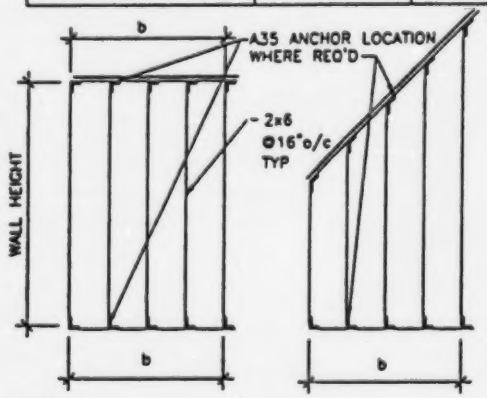


PLAN VIEW
NTS

NOTE: FOR GABLE END WALLS, ROOF LOAD TRIBUTARY = 2 x OVERHANG

TABLE 3B– MAXIMUM WALL HEIGHT FOR LOADBEARING WALLS WITHOUT OPENINGS–2x6 @ 12"o/c FULL HEIGHT STUDS

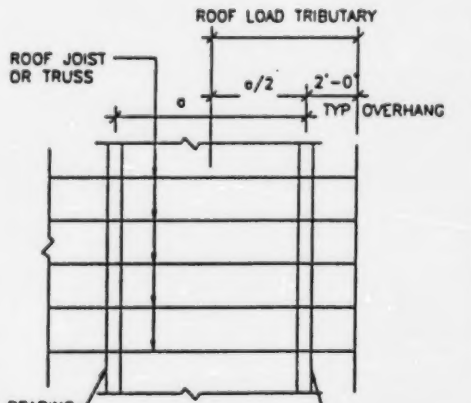
WIND LOAD	SNOW LOAD	ROOF LOAD TRIBUTARY (o/2 + OVERHANG)				
		0 to 4'–0"	8'–0"	12'–0"	15'–0"	18'–0"
		WALL HEIGHT				
HIGH 3 NAILS PER STUD + 1–A35 FRAMING ANCHORS	HIGH	17'–3" (5258mm)	16'–6" (5029mm)	16'–1" (4902mm)	15'–10" (4826mm)	15'–7" (4750mm)
	MEDIUM	17'–3" (5258mm)	17'–0" (5182mm)	16'–6" (5029mm)	16'–3" (4953mm)	16'–1" (4902mm)
	LOW	17'–4" (5283mm)	17'–0" (5182mm)	16'–9" (5105mm)	16'–6" (5029mm)	16'–3" (4953mm)
MEDIUM 3 NAILS PER STUD	HIGH	18'–8" (5690mm)	18'–2" (5537mm)	17'–8" (5385mm)	17'–5" (5309mm)	15'–10" (4826mm)
	MEDIUM	18'–8" (5690mm)	18'–6" (5639mm)	18'–2" (5537mm)	17'–8" (5385mm)	17'–6" (5334mm)
	LOW	18'–10" (5740mm)	18'–8" (5690mm)	18'–4" (5588mm)	18'–2" (5537mm)	18'–0" (5486mm)
LOW 3 NAILS PER STUD	HIGH	20'–9" (6325mm)	20'–3" (6172mm)	19'–6" (5944mm)	18'–8" (5690mm)	17'–8" (5385mm)
	MEDIUM	21'–2" (6452mm)	20'–7" (6274mm)	20'–2" (6147mm)	19'–9" (6020mm)	19'–6" (5944mm)
	LOW	21'–2" (6452mm)	20'–9" (6325mm)	20'–4" (6198mm)	20'–1" (6121mm)	19'–9" (6020mm)
LAKE LOUISE 3 NAILS PER PLATE	VERY HIGH	20'–6" (6248mm)	19'–5" (5918mm)	17'–0" (5182mm)	15'–8" (4775mm)	14'–9" (4496mm)



NOTE:
b IS UNLIMITED

WALL ELEVATION
NTS

WALL ELEVATION
(SLOPED ROOF)

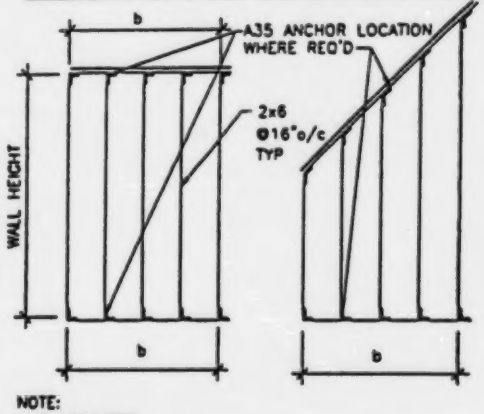


PLAN VIEW
NTS

NOTE: FOR GABLE END WALLS, ROOF LOAD TRIBUTARY = 2 x OVERHANG

TABLE 3C– MAXIMUM WALL HEIGHT FOR LOADBEARING WALLS WITHOUT OPENINGS–2x8 @ 16"o/c FULL HEIGHT STUDS

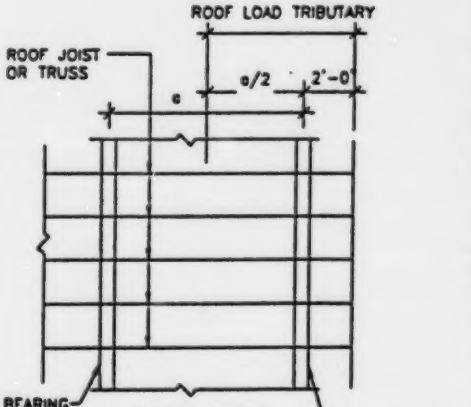
WIND LOAD	SNOW LOAD	ROOF LOAD TRIBUTARY (o/2 + OVERHANG)				
		0 to 4'-0"	8'-0"	12'-0"	15'-0"	18'-0"
		WALL HEIGHT				
HIGH 4 NAILS PER STUD + 1-A35 FRAMING ANCHORS	HIGH	20'-7" (6274mm)	20'-3" (6172mm)	19'-10" (6045mm)	19'-0" (5791mm)	18'-4" (5588mm)
	MEDIUM	20'-9" (6325mm)	20'-6" (6248mm)	20'-2" (6147mm)	20'-0" (6096mm)	19'-9" (6020mm)
	LOW	20'-9" (6325mm)	20'-7" (6274mm)	20'-4" (6198mm)	20'-2" (6147mm)	20'-0" (6096mm)
MEDIUM 3 NAILS PER STUD	HIGH	22'-5" (6833mm)	22'-0" (6706mm)	21'-5" (6528mm)	20'-8" (6299mm)	19'-9" (6020mm)
	MEDIUM	22'-6" (6858mm)	22'-2" (6756mm)	22'-0" (6706mm)	21'-7" (6579mm)	21'-5" (6528mm)
	LOW	22'-7" (6883mm)	22'-4" (6807mm)	22'-0" (6706mm)	21'-9" (6629mm)	21'-7" (6579mm)
LOW 3 NAILS PER STUD	HIGH	25'-1" (7645mm)	24'-4" (7417mm)	23'-8" (7214mm)	22'-8" (6909mm)	21'-6" (6553mm)
	MEDIUM	25'-4" (7722mm)	24'-9" (7544mm)	24'-4" (7417mm)	23'-11" (7290mm)	23'-7" (7188mm)
	LOW	25'-4" (7722mm)	24'-11" (7595mm)	24'-8" (7468mm)	24'-4" (7417mm)	24'-0" (7315mm)
LAKE LOUISE 3 NAILS PER PLATE	VERY HIGH	24'-7" (7493mm)	23'-1" (7036mm)	20'-7" (6274mm)	19'-0" (5791mm)	18'-0" (5486mm)



NOTE:
b IS UNLIMITED

WALL ELEVATION
NTS

WALL ELEVATION
(SLOPED ROOF)

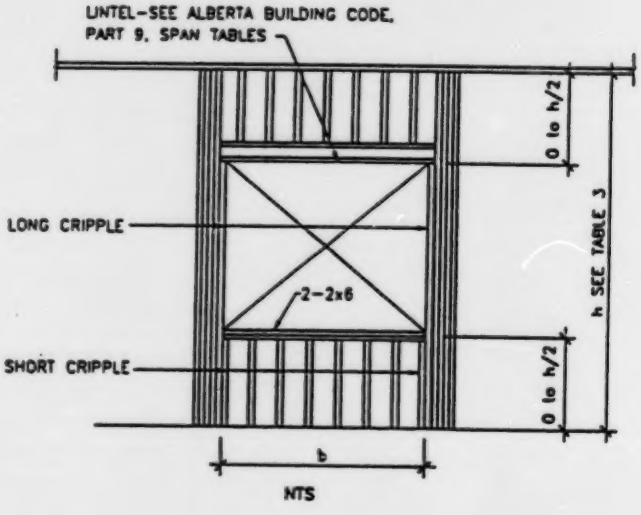


PLAN VIEW
NTS

NOTE: FOR GABLE END WALLS, ROOF LOAD TRIBUTARY = 2 x OVERHANG

TABLE 4– NUMBER OF FULL HEIGHT 2x6 OR 2x8 STUDS REQUIRED ON EACH SIDE OF WINDOW OPENINGS 4'–0" TO 10'–0" WIDE FOR LOADBEARING WALLS WITH UP TO THREE STACKED WINDOWS OF ANY HEIGHT

OPENING WIDTH b	WALL CONFIGURATIONS		
	2x6 @ 16"o/c	2x6 @ 12"o/c	2x8 @ 16"o/c
b=4'–0"	2–2x6	3–2x6	2–2x8
b=4'–8"	3–2x6	3–2x6	32x8
b=6'–0"	3–2x6	4–2x6	3–2x8
b=7'–0"	4–2x6	4–2x6	4–2x8
b=8'–0"	4–2x6	5–2x6	4–2x8
b=10'–0"	5–2x6	7–2x6	5–2x8



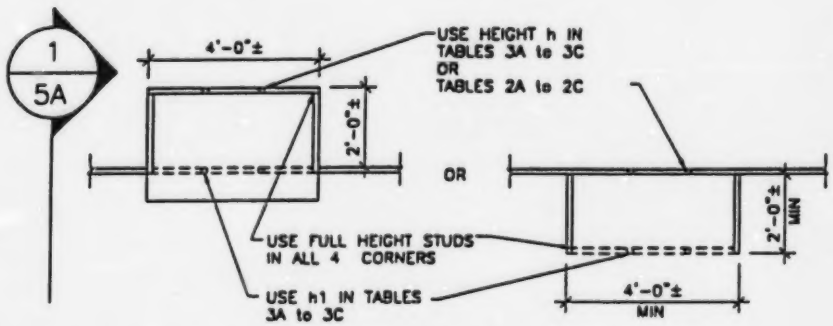
NOTE:
WHERE WINDOW WIDTH EXCEEDS 75% OF THE LENGTH OF THE WALL, ENGINEERING DESIGN IS REQUIRED TO PREVENT RACKING SHEAR.

FOR NAILING REQUIREMENTS, REFER TO TABLES 3A , 3B , & 3C.

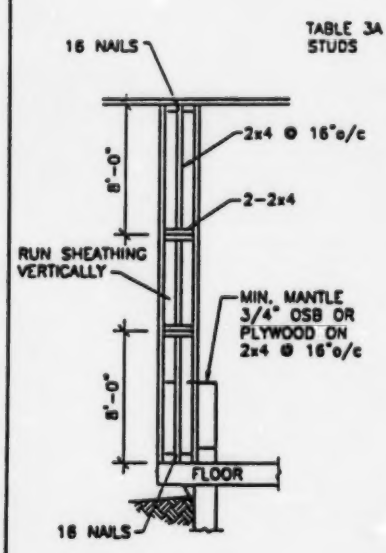
NOTE: SOME THERMAL BRIDGING CAN BE EXPECTED WHERE MORE THAN 2–2x6 USED.

TABLE 5A –REQUIREMENTS FOR FIREPLACES NOT LOCATED AT CORNERS

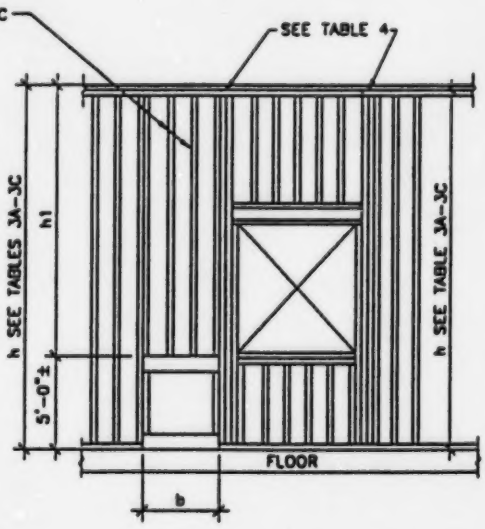
1. FOR WIDTH 'b' (MIN 3'–6") h, MAY BE USED AS THE WALL HEIGHT IN THE SELECTION OF STUDS OVER FRONT OF HEARTH. USE TABLES 3A–3C.
2. FOR ADJACENT WINDOWS, DO NOT REDUCE THE NUMBER OF FLANKING STUDS REQUIRED BY TABLE 4.
3. USE TABLES 3A TO 3C FOR SELECTION OF FULL HEIGHT STUDS ON EITHER SIDE OF THE FIREPLACE.
4. SHEATHING: MIN. 1/2" PLYWOOD OR OSB. RUN SHEETS VERTICALLY WITH FULL HEIGHT SHEET TOP AND BOTTOM.



PLAN



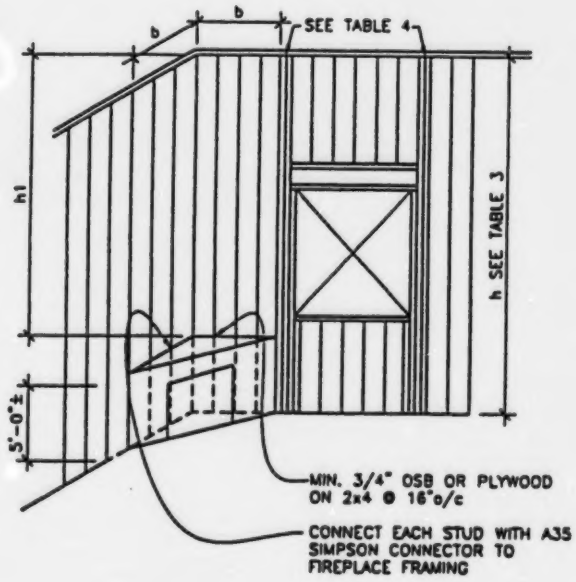
SECTION 1
NTS



ELEVATIONS

TABLE 5B–REQUIREMENTS FOR FIREPLACES LOCATED AT CORNERS

1. FOR WIDTH 'b' (MIN 3'–6") h_1 MAY BE USED AS THE WALL HEIGHT IN THE SELECTION OF STUDS OVER FRONT OF HEARTH. USE TABLES 3A–3C.
2. FOR ADJACENT WINDOWS, DO NOT REDUCE THE NUMBER OF FLANKING STUDS REQUIRED BY TABLE 4.
3. FOR MASONRY FIREPLACES, SUPPORT MAY BE AVAILABLE WITH SUITABLE REINFORCING. CONSULT A STRUCTURAL ENGINEER.
4. MAY USE FOR WALL VENTED OR VERTICAL CHIMNEY FIREPLACES.



ELEVATIONS
NTS

Table 1 lists each of the live load classifications in terms of their upper limits, and provides example listings of centres included in each classification. In practice, if a builder needs to determine the load classifications of a centre not listed in Table 1, he would look up the actual values in Appendix C of the Code, then determine the classification in terms of Table 1. For example, St. Albert is not listed in Table 1. From Appendix C of the code, the ground snow load in St. Albert is 1.6 kPa, and the 1-in-30 hourly wind pressure is 0.41 kPa. Referring to Table 1, the snow load value is higher than the reference value for low snow load, but lower than the reference value for medium snow load. The snow load classification for St. Albert, therefore, is 'Medium'. Similarly, the wind load classification for St. Albert is determined to be 'Low'.

6.2 Tall Walls Constructed in Two Vertical Sections

Tables 2A, 2B and 2C (collectively referred to as Table Set 2) describe the requirements that must be met when walls up to the specified heights (16ft, 18ft and 20ft) are required (or desired) to be built in two lifts. This allows for the construction of tall walls using easily manageable lengths of dimension lumber. The work can be done by a normal framing contingent -- the requirement for additional manpower or equipment to lift a full height tall wall into place can often be avoided.

The limiting criterion established for the development of these tables was deflection. Specifically, allowable deflection was set at 1/180 of wall span (width). Calculations were done without consideration to the effects of interior and exterior cladding (sheathing, drywall, etc.). These elements are recognized to have a stiffening effect on the wall, but quantification of their effect is incalculable.

The tables specify walls 'up to' the indicated heights. Table 2A can be used for walls higher than the limit presently contained in Part 9 of the code (ABC, Table 9.23.10.1) to a maximum of 16 feet high. Table 2B can be used for walls over 16 feet high but less than or equal to 18 feet high, and Table 2C can be used for walls more than 18 feet high but less than or equal to 20 feet high.

Lateral loads govern in Table Set 2. Lake Louise would normally be included in the Low Wind column of the tables. However, it is specified in a distinct column because of the uniquely high snow load in the area; determination of the allowable width took that high snow load into account. Allowable widths in the Lake Louise area are therefore somewhat lower than in other low wind areas.

The High Wind load classification places the greatest restriction on allowable width. The project objective requires that generic designs accommodate walls from 7' to 16' in width. From Table Set 2 it can be seen that, with the two-lift construction method, this requirement can be met only in areas classified as low wind loading, using the 4-member intermediate plate detail. Other load classification areas must use tables derived for construction using full-height stud members.

The intermediate plates must be continuous from one end of the tall wall to the other. They cannot be interrupted by window openings. Despite this apparent limitation, the table is inherently versatile in that the intermediate plates are not required to be at the half height point in all instances. The location can be adjusted to suit the location of a window opening. For instance, a 16ft high wall which may have been built using 2 – 8ft lifts can also be built using a 10ft lift and a 6ft lift to suit a window opening that 2 – 8ft lifts would not accommodate.

Note from the tables that two-lift tall walls are required to be supported at either end by full-height walls at least 8 feet long. Additionally, 'A35 framing anchors' are specified as requirements in

some conditions. These are three-way galvanized metal anchors, intended to tie the intermediate plate members to the bracing walls.

6.3 Tall Walls Constructed From Full-Height Stud Member

Tables 3A, 3B and 3C (collectively referred to as Table Set 3) specify construction requirements for tall walls built from full-length stud materials. In these tables, width is not a constraining factor. Allowable height is a function of wind and snow loads in combination, and roof load tributary[3].

In order to meet the project objective for height (up to 20' in all areas of Alberta), different material configurations had to be considered. For the most severe loading conditions (high wind, high snow) tall walls 20' in height must be built using 2x8 framing materials at 16" on center, and the roof load tributary must be no greater than 8' in length (Table 3C). For the lightest load conditions (low wind, low snow), tall walls 20' in height must be built using 2x6 material at 12" on center, and the roof load tributary can be no more than 15 feet in length (Table 3B). With framing consisting of normal material and spacing (2x6 at 16" on center), maximum allowable wall heights are less than 20' for all load combinations and tributary conditions (Table 3A).

6.4 Window Openings

Windows can be accommodated in the tall walls described by Table Sets 2 and 3 by the installation of full height flanking studs on both sides of the openings. To accommodate window openings in both types of walls, Table 4 was developed. Table 4 specifies the number of flanking studs that must be installed on either side of windows installed in tall walls. Essentially, the number of studs interrupted by the opening is the total number of flanking studs that must be installed; half of the total must be installed on each side (see Appendix 3, "Other Structural Analyses" for the expression defining the number of flanking studs required). Flanking studs are additional to the width-defining innermost studs which are installed from the bottom surface of the lintel to the bottom plate.

Table 4 applies for tall walls with up to 3 windows, vertically stacked, of any height. It applies to both of the framing methods covered by Table Sets 2 and 3.

In the case of Table Set 2, window openings can not interrupt the intermediate plate. As noted previously, the height of the intermediate plate can be adjusted to suit window openings. For windows in the top sector (the area of the wall from the top plate to the intermediate plate) the required number of flanking studs are required above the intermediate plate only. Likewise, for windows in the bottom sector, the required number of flanking studs are required below the intermediate plate only.

In the case of Table Set 3, where windows of differing width are stacked vertically, full-height flanking studs are required for the wider opening and:

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[3] The roof load tributary area is the proportionate horizontal projection of roof area deemed to transmit load to a single stud member. In this work, the width of the tributary area is the stud spacing. The length of the tributary area is the eave overhang (typically 2-ft.) plus ½ the perpendicular distance from the exterior loadbearing wall to the next loadbearing structure. This could be an interior wall or, in the case of clear spans, the opposite exterior wall. In Tables 3A, 3B and 3C, the roof load tributary is represented by its length only. The width is variable (12" or 16"), and is factored into the calculations.

- the studs for the narrower window must extend from the top wall plate to the lintel of the wider window where the narrower window is above, or
- the studs for the narrower window must extend from the bottom wall plate to the sill framing of the wider window where the narrower window is below.

When the requirements of Table 4 are followed, there is no restriction on heights of window openings; however, window widths should not exceed 75% of wall width. Widths greater than 75% may render the wall prone to racking shear, and this circumstance should be dealt with by individual engineering design.

Lintels for window openings must be selected from the Alberta Building Code, Article 9.23.12.3, Lintel Spans and Sizes.

6.5 The Effect of Wall Features and Appurtenances

Within the scope of the work, the structural contributions of feature ledges, window ledges, fireplaces, non-structural interior partition walls and hip roof trusses were assessed.

6.5.1 Ledges

The structural contributions of ledges (horizontal beams finished to match or complement interior décor) are minor. From the generic design perspective, no impact on table sets 2 and 3 was warranted. A generic design must attempt to account for worst case conditions. If a house design specifies a ledge on a tall wall, and the ledge is less than the full width of the tall wall, it cannot be assumed that the ledge provides additional strength over the full span of the wall. The generic design must address that portion of the wall not affected by the ledge.

If a ledge spans the full width of the tall wall, the problem becomes one of too many potential variables that can affect the contribution but cannot be adequately addressed by a generic design document. These include the particular materials used, the method of fastening to the tall wall and end walls, the cross-sectional dimensions of the ledge member, and the vertical position of the ledge.

6.5.2 Interior Partitions and Hip Roof Trusses

As was found for ledges, the contributions of interior partition walls and hip roof trusses are minor and, when these elements are used, no adjustment of the data in table sets 2 and 3 is warranted.

In the case of interior partition walls of less than full height, no lateral support is provided unless the load is satisfactorily transferred to a loadbearing component. Without adequate load transfer, any structural support offered by the partition wall would be compromised by racking forces.

Where hip roof trusses are used, the roof load tributary varies linearly with distance along the tall wall, as indicated in Figure 2.

Based on a typical overhang of 2ft, the tributary length is calculated as x/2 + 2 for the hip roof section, and varies from 2ft at each end to X/2 + 2ft at the center. A generic design, however, should address the worst case condition which exists at the center. The variable tributary length of

the hip roof section should not therefore be a factor in the design of generic requirements for tall wall construction.

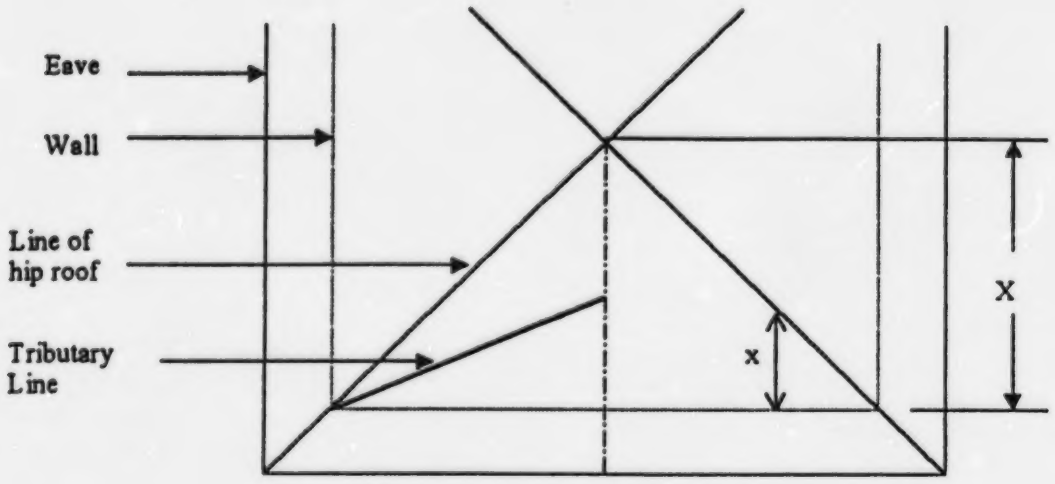

Figure 2 – Hip Roof Tributary

6.5.3 Fireplaces

Tables 5A and 5B describe framing requirements when tall walls include fireplaces along their spans (Table 5A) and at corners (Table 5B). As can be seen from these tables, fireplaces do not generally improve the strength of loadbearing tall walls. Some relaxation of the framing requirements can be accomplished for chimney chase construction, as follows:

- Framing of the sidewalls of the chase can include 2x4 lumber as shown by Section 1 of Table 5A. Note that the corner studs of the sidewall sections must be full-height members selected from Table 3A, and that sheathing of the sidewall sections must be minimum ½" thick and installed in a specified pattern (full height sheets at top and bottom, cut sheet at middle).
- Intermediate studs over the front face of the chase section can be selected by considering the effective design height of the wall, for the width of the fireplace only, to be the design height of the wall less the fireplace mantle framed height. For example, assume a wall 19'-6" high and 13'-0" wide is required to be built in an area of medium wind load and medium snow load, and the wall is to include a fireplace 4ft wide and 5ft high. The wall can be built using either Table 2C or Table 3C. Framing above the front face of the

mantle section can be selected by considering the required height to be 14'-6". Options for this section of wall now include all of Table set 2 (4-plate sections) and all of Table set 3 (medium wind, medium snow category). Table 3A would probably be chosen on the basis of cost effectiveness.

- Where windows are immediately adjacent to a fireplace (as depicted by the elevation sketches of Tables 5A and 5B) the requirement for flanking studs at the window cannot be diminished by virtue of any of the fireplace framing requirements.

6.6 Design Assumptions and Limitations

Several design conditions must be recognized in the use of these tables. These conditions are noted at appropriate places in the discussion in Appendix 2, where an illustration of the calculation method is presented. In summary, they include:

- The dead load is assumed as 1kPa throughout.
- Live loads are limited to those produced by snow and rain. It is assumed that there is no occupancy load associated with the roof, and no equipment load associated with the roof.
- Earth and hydrostatic pressures are not included as considerations in this work. It is assumed that there is no earth loading against the walls under consideration.
- Loading effects due to contraction and expansion are minimal with wood members, and are taken as zero for this work.
- Load effects due to vibration are taken as negligible.
- Internal pressures caused by wind are taken as negligible.

6.7 Materials and Field Conditions

The work is based on the use of SPF#2 or better framing materials. Notching of the framing members is not permitted. Studs may be drilled, as indicated in ABC 9.23.5, but only within 16" of the bottom of the studs.

The walls were not designed to carry the load of full height brick veneer cladding. Such cladding may be used to a maximum of 4ft high on the loadbearing tall walls encompassed by this design work.

7 Use of the Tables

Examples describing the use of the tables to select appropriate tall wall construction details are provided in Appendix 1.

8 Conclusions

Using the tables developed within the scope of this project, it is possible for builders to select structurally correct construction details for loadbearing walls beyond the height limits presently contained in the Alberta Building Code, 1997. In many instances, the tables will provide more than one design solution for a given set of wall properties.

The tables will not apply to all projects. For instance, where any of the design assumptions of the previous section do not apply to a particular project or region, the tables are likewise not applicable. Further, it has been noted that the structural contributions of particular wall features like ledges have not been included in the tables, because a generic design cannot possibly address all of the variables that can exist. If a particular project includes this type of wall feature and its structural contribution must be identified, individual professional design analysis will be required.

Appendix 1 – Examples on the Use of the Tall Wall Tables

Example 1

Plans for a house in Banff call for a wall 16'-0" high with a 16'-0" span. The wall must include a 6' wide by 8' high window. The roof loading tributary is 10'.

Step 1 – Determination of Loading Characteristics

Refer to Table 1 to determine the loading characteristics for Banff. Table 1 indicates that snow load is high, and wind load is low.

Step 2 –Determination of Framing Requirements.

Table Set 2:

The example fits the Low Wind loading column. In Table 2A, the 2-member intermediate plate detail does not allow the necessary width. The 4-member intermediate plate detail may be used for the wall. This detail allows for wall widths up to 17'-1" and roof load tributaries up to 18'. Similarly, the 4-member intermediate plate detail of Table 2B also suits the dimensional specifications of the wall. Table 2C does not contain a solution for the wall.

Table Set 3

The example fits the Low Wind Load row, High Snow Load sub-row of the tables. The 12'-0" Roof Load Tributary column must be used, since the tables do not include a 10' tributary column. Wall span is not a factor in Table set 3. All of the tables in set 3 contain acceptable construction configurations for the example wall: Table 3A allows a height of 17'-6"; Table 3B allows a height of 19'-6", and Table 3C allows a height of 23'-8".

Step 3 – Determine framing requirements for the window opening.

Enter Table 4 at Opening Width = 6'-0". Assuming the wall configuration from Table 3A is selected (2x6 @ 16"), Table 4 specifies that 3 studs are required on each side of the window opening. In the case of Table Set 3, these are full-length studs and are additional to the innermost studs extending from the underside of the lintel to the bottom plate. If Table 2A or 2B is chosen, the elevation of the intermediate plate must be adjusted as necessary such that the window opening is fully in the top sector or fully in the bottom sector. The flanking studs will then be required in only the top or bottom sector accordingly.

Step 4 – Determine the window lintel requirements.

From Table S17 of the Alberta Building Code, the builder would choose a window lintel size of 2 - 2 x 10 (38 x 235), assuming the lintel material is to be SPF#2 or better.

From this example, it can be seen that several solutions may exist for any one tall wall configuration. The builder can select the appropriate configuration based on manpower, material, and overall cost considerations.

Example 2

A home in Rocky Mountain House requires a tall wall 18' high by 16' wide. The plans indicate a roof load tributary of 12'. The wall includes two window openings – the lower opening, with its sill at 2'-6" above the sub-floor, is 10' wide and 6' high. The upper opening is centered over the lower opening. Its dimensions are 4' wide by 2' high. Its sill is 2'-0" above the top of the lower window opening. The builder has determined that he must use a two-lift construction method.

Step 1 – Determination of Loading Characteristics from Table 1.

Since the loading characteristics for Rocky Mountain House do not appear in Table 1, the builder must first refer to Appendix C of the Alberta Building Code, 1997. Appendix C indicates a snow load of 1.7kPa, and a 1-in-30 wind load of 0.40kPa for Rocky Mountain House. Comparing these loads to the Table 1 ranges, the builder determines that the appropriate loading characteristics are medium snow load and low wind load.

Step 2 – Determination of Framing Requirements

Since the builder has determined that a two-lift method must be used, options are limited to Table Set 2. Table 2A does not offer an acceptable detail, since its upper height limit is 16'-0". Table 2B does offer an acceptable solution – an 18' high wall can be up to 16'-6" wide in the low wind loading category using 2x6 SPF#2 or better studs at 16" on center, providing the 4-member intermediate plate detail is used.

Step 3 – Determination of Framing Requirements for the Window Openings

For the lower window, enter Table 4 at 'b' = 10'-0". For 2x6 framing at 16" on center, 5 studs are required on each side of the window opening. These flanking studs must be continuous from the intermediate plate to the bottom plate.

For the upper window, enter Table 4 at 'b' = 4'-0". For 2x6 framing at 16" on center, 2 studs are required on each side of the window opening. These studs must be continuous from the top plate to the intermediate plate.

Step 4 – Determine the window lintel requirements.

For the lower window, the required lintel span is 10'-0" (3.05m). Table S18 in the ABC 1997 may be used for this span, and the lintel selected would be 2 – 2x12 (38x286). For the upper window, the lintel would be 2 – 2x4 (38x89) or 2 – 2x6 (38x140).

Note from this example that if the required wall height was 19' instead of 18', Table Set 2 would not provide a solution and the builder would have to modify his approach by using additional framing crew or using hoisting equipment to lift a full height wall into place. The builder would also have to abandon his plans to use Table Set 2 for construction of the wall if the height of the intermediate plate could not be adjusted to suit a required window opening.

Appendix 2 – Illustration of Design Method

Sample Derivation

Both strength and deflection limits were checked in the generation of each individual data point. The following description illustrates the derivation of the relationships required to generate a maximum height data point. This derivation will also illustrate how the analytic methods are tied into the requirements of the Alberta Building Code (1997), and will identify the major assumptions made.

Loads

A first step in the analysis is the identification and classification of loads acting on the system (in this analysis, the "system" is the exterior loadbearing stud). Sentence 4.1.3.2 (3) of the Alberta Building Code defines the combination of live and dead loads on a loadbearing structure as

$$FLC = \{\alpha_D D + \gamma\psi[\alpha_L L + \alpha_W W + \alpha_T T]\}A \qquad \text{Equation 1}$$

where

D = dead loads, kPa

L = live load due to static or inertia forces arising from intended use and occupancy (includes loads due to cranes); snow, ice and rain; earth and hydrostatic pressure, kPa. For this work, live loads are limited to snow and rain. It is assumed that there is no occupancy load associated with the roof, and no equipment load associated with the roof. Likewise, earth and hydrostatic pressures are not included as considerations in this work. It is assumed that there is no earth loading against the walls under consideration.

W = live load due to wind, kPa

T = effects due to contraction or expansion. 'T' is assumed as zero for this work

and

α_D = dead load factor = 1.25

α_L = inertia live load factor = 1.5

α_W = wind live load factor = 1.5

α_T = contraction/expansion live load factor = 1.25 (not relevant in this analysis, since 'T' has been taken as zero)

and

γ = importance factor = 1.0

ψ = the load combination factor, = 1.0 when only one of the loads, L, W and T acts; = 0.70 when 2 of the loads, L, W and T act, and = 0.60 when all of the loads, L, W and T act,

and

A = the load tributary area (m^2), which, in this work, is the proportionate horizontal projection of roof area deemed to transmit load to a single stud member. In this work, the width of the tributary area is the stud spacing. The length of the tributary area is the eave overhang (typically 2-ft.) plus ½ the perpendicular distance from the exterior loadbearing wall to the next loadbearing structure. This could be an interior wall or, in the case of clear spans, the opposite exterior wall. Note that Equation 1in the Code representation does not include 'A' – that is, the load is a per unit area representation. Inclusion of 'A' in this work translates the quantity into the load carried by each stud member. (Note: when the lateral load per stud member is required, 'A' is replaced with 'b_s', the stud spacing. Each stud carries a 16"-wide (or other spacing width) increment of lateral load).

Dead loads (D) to be supported by the loadbearing walls are assumed to be 1.0 kPa throughout the analysis. Some argument might be made in support of calculated dead loads in the order of 0.75 kPa. However, future re-roofing directly over existing roofing is not uncommon, and this tends to increase the dead load. The assumed value of 1.0 kPa will help to ensure future adequacy of the loadbearing walls.

Live load (L) is restricted to snow loading and the associated rain load, since the load originates from the roof, and there is no occupancy load on the roof nor is there (generally) any significant equipment loading on residential roofs. Snow loading is defined in Subsection 4.1.7 of the ABC. The code user is directed to Subsection 2.2.1, which in turn directs him to Appendix C, which identifies the ground snow load typical to various centres in the province. Roof snow loading, S, is defined in 4.1.7.1 as

$$S = S_S(C_b C_w C_s C_a) + S_r \qquad \text{Equation 2}$$

where

S_s = the ground snow load in kPa, specified in Appendix C

S_r = the associated rain load in kPa, specified in Appendix C

C_b = the basic roof snow load factor of 0.8,

C_w = the wind exposure factor of 1.0 (may be reduced under certain conditions not applicable to this analysis)

C_s = the slope factor of 1.0 (may also be reduced under certain conditions not applicable to this analysis)

C_a = the accumulation factor of 1.0 (may also be reduced under certain conditions not applicable to this analysis).

Substituting numerical values yields

$$S = 0.8S_s + S_r \qquad \text{Equation 3}$$

as the specified snow load for any location in Alberta. (Part 9 of the ABC also contains a reference for determining specified snow loading, which lowers the value of C_b to 0.5 or 0.6. However, this applies to circumstances under which loaded member spacing does not exceed 400mm, and this condition cannot be guaranteed to hold true throughout this analysis.)

Appendix C lists individual snow loads for numerous centres. To ease calculations and reduce the sheer number of resultant tall wall height (and width) tables, the range of snow loads in code Appendix C was divided into 4 categories – low, medium, high and very high. These ranges were assigned the following limits:

Low Snow = 1.0 to 1.3 kPa

Medium Snow = 1.4 to 1.9 kPa

High Snow = 2.0 to 3.3 kPa

Very High Snow = 3.4 kPa to 6.3 kPa.

The upper limit of the classification group is the number used in calculations involving snow loads.

Wind load (W) is defined by ABC Article 4.1.8.1(1) as

$$p = qC_eC_gC_p \qquad \text{Equation 4}$$

where

p = the specified external pressure (kPa) acting statically and in a direction normal to the surface either as a pressure directed towards the surface or as a suction directed away from the surface.

q = the reference velocity pressure in kPa;

C_e = the exposure factor of 1.0

C_g = the gust effect factor of 2.0

C_p = the external pressure coefficient, averaged over the area of the surface considered. The value of C_p can vary, depending upon the roof configuration. A value of 0.5 was chosen for this work.

The above factors (C_e, C_g, C_p) may be assigned other values for certain conditions, none of which are applicable to this analysis. Net wind pressure includes consideration of internal pressures caused by wind. In this analysis, internal pressures caused by wind are ignored.

Substituting numerical values for the load factors of Equation 4 yields

$$p = q \qquad \text{Equation 5}$$

Where

$q = q_{10}$, the 1-in-10 year occurrence value of q specified in Appendix C, or

$q = q_{30}$, the 1-in-30 year occurrence value of q specified in Appendix C.

The Alberta Building Code requires that the1-in-10 value of q be used in the design of structural members for deflection and vibration criteria (vibration analysis does not generally apply to single family dwellings, and was not done as part of this work0. The 1-in-30 value of q is to be used in the design of structural members for strength criteria.

Like snow loads, wind loads are listed in Appendix C. The 1-in-30 year wind loads listed in Appendix C were also categorized into general classifications resulting in the following groups:

Low Wind = 0 to 0.46 kPa

Medium Wind = 0.47 to 0.69 kPa

High Wind = 0.70 kPa to 0.93 kPa.

As for snow loading, the upper limit of a wind classification group is the number used in calculations involving wind loads.

Limit States Relationships

For this derivation (determining a maximum height data point), the governing limit states relationship for strength is:

$$\frac{M_f}{M_r} + \frac{P_f}{P_r} \leq 1 \qquad \text{Equation 6}$$

where

M_f = Factored bending moment, kNm

M_r = Factored moment resistance, kNm. For short duration loads such as wind gusts, a 1.15 multiplication factor (load duration factor) is imposed.

P_f = Factored axial compression load, kN

P_r = Factored compression resistance, kN. For short duration loads such as wind gusts, a 1.15 multiplication factor (load duration factor) is imposed.

The equation governing deflection is

$$\Delta \leq \frac{h}{180} \qquad \text{Equation 7}$$

where

Δ = allowable deflection, in same units as h

h = the height of the wall.

For determination of allowable loadbearing wall heights, the governing limit states criteria are mathematically manipulated such that the height (h) of the wall is expressed in terms of loading and structural properties of the member.

Determination of the maximum allowable height is a successive trial process. The design engineer selects a first-use value, which by intuition and expertise is assumed to be a reasonable approximation. The estimate is examined in terms of both the limiting criteria – strength and serviceability (deflection). The relationship yielding the lower allowable height becomes the governing criterion, and future iterations are subjected to the calculations defining that criterion only. When the iterated height and the resultant calculated height are within an acceptable tolerance (Calculated – Iterated < 0.1m), the calculation is complete.

Derivation of Governing Equations

From Equation 6, M_r is a known characteristic (2.58kNm for SPF#1,2). P_f (the imposed axial load) can be calculated from Equation 1, setting wind load (W) to zero.

P_r, the factored axial load resistance, is a known characteristic for a given length of stud.

M_f, the factored bending moment, must take into account the amplified moment due to axial loading (snow load and dead load) on a laterally loaded (wind load) member. M_f can be calculated from

$$M_f = \alpha \frac{w_f h^2}{8} \qquad \text{Equation 8}$$

Where

α = the moment magnification factor, and

W_f = the factored lateral load acting over the lateral width of load carried by the stud, kN/m . The lateral width of load carried by the stud is the stud spacing. W_f must be calculated using q_{30} , the 1-in-30 year wind load for a given area.

The magnification factor is given by

$$\alpha = \frac{1}{1 - \frac{P_f}{P_E}} \qquad \text{Equation 9}$$

where

P_E = the Euler Buckling Load in the direction of bending, kN.

The buckling load is in turn given by

$$P_E = \frac{\Pi^2 E_s I}{h^2} \qquad \text{Equation 10}$$

where

$E_S I$ = the flexural stiffness, N(mm)^2. For SPF#1,2, $E_S I$ = 82.5 x 109 N(mm)^2

Solving Equation 6 in terms of Equations 8, 9, and 10 yields

$$h \le \sqrt{\frac{8M_f}{\alpha W_f}\left(1 - \frac{P_f}{P_r}\right)} \qquad \text{Equation 11}$$

From Equation 11, the iterative nature of the calculation can be seen. 'h,' the maximum allowable height of wall sought, is dependent upon α, which itself is dependent upon h^2.

Equation 7 can be expanded in terms of the variables and unknowns needed to determine the limiting wall height from the deflection limit state, as follows:

$$\Delta = \frac{5W_S h^4}{384E_S I}\alpha \le \frac{h}{180} \qquad \text{Equation 12}$$

which, solving for 'h', yields

$$h \le \sqrt[3]{\frac{0.427E_S I}{W_S \alpha}} \qquad \text{Equation 13}$$

where

W_S = the service lateral load, calculated using q_{10}, the 1-in-10 year value of the wind load for a particular area.

Equations 11 and 13 are the expressions used in the determination of the maximum allowable height of a 2x6 stud wall framed from continuous members.

Other Structural Analyses

Methods similar to those described above were employed to determine maximum allowable wall widths for two-lift construction, and for the determination of structural benefits that may be provided by the various wall appurtenance items (ledges, stairs, fireplaces, hip roofs, interior partitions) included in the scope of the work.

To identify necessary framing requirements for various sizes of window openings in tall walls, the task was to determine the number of supporting studs required on either side of the openings. Existing code instruction (Subsection 9.23.12) defines requirements for lintels over window openings. A generally accepted and structurally sound industry standard was used to determine the number of additional studs required adjacent to the openings – the number of studs interrupted by the opening is the total number of additional flanking studs required. For 16" stud spacing, this can be represented arithmetically by:

$$n = \frac{3a + 4}{8} \qquad \text{Equation 14}$$

where

n = the number of full height studs required on each side of the opening. Round up to the next highest whole number.

a = the width of the opening, ft.

Example Determination

The following example will illustrate the determination of the maximum allowable exterior loadbearing wall height for Lethbridge. The wall is to be constructed from full length, 2x6 SPF#2 or better studs. Studs are to be on 16" (400mm) centers, and the length of the vertical load tributary area is 15 ft.

Properties of the material

For 2x6 SPF#2 or better,

M_r = 2.58kNm. (factored moment resistance for normal load duration)

$E_S I = 82.5 \times 10^9$ N(mm)^2 (flexural stiffness)

From Appendix C, Alberta Building Code, 1997, Lethbridge snow loads of S_s = 1.1kPa and S_r = 0.1kPa, and wind loads of q_{30} = 0.76kPa and q_{10} = 0.64kPa. Therefore, from Table 1, Appendix 1 (of this report), the snow loads for Lethbridge is low, and the wind load is high, and, for calculation purposes,

S_s = 1.3 kPa

S_r = 0.1 kPa

q_{30} = 0.93 kPa

q_{10} = 0.74 kPa

From Equation 3, S = 1.14 kPa.

From Equation 5, q_{10} = 0.74 kPa, and q_{30} = 0.93 kPa.

Calculation of Loading Parameters

Using Equation 1, P_f is calculated as 5.50kN. In Equation 1, W is set to zero, since P_f is a vertically acting load. Other variables are as shown in the definition of Equation 1.

The short term load duration factor of 1.15 is applied to M_r to yield M_r = 2.967 kNm.

W_f is determined from Equation 1. All loads except wind are set to zero; wind load is established from q_{30}. To identify W_f as a load per stud, the stud spacing is applied to Equation 1 as a multiplier ('A' is replaced by 'b_s', because each stud carries a 16"-wide increment of lateral load). W_f is thereby calculated as 0.567 kN/m.

The first calculation for L is done using an estimated value of 4.42m (14 ½ ft). From Equation 10, P_E is calculated as 41.7kN, and from Equation 9, α is determined to be 1.152.

At 4.42m, P_r for SPF#2 or better is known to be 20.32. Applying the 1.15 short term load duration factor yields P_r = 23.368 kN.

Substituting known and calculated values into Equation 11(the limit state criterion for strength) yields $h \leq 5.272$m. Substituting known and calculated values into Equation 13 (the limit state criterion for deflection) yields $h \leq 4.662$m.

Since the deflection limit state yields the lower allowable height, Equation 13 becomes the governing criterion. The calculated value of 'h' (4.662m) and the trial value (4.442m) are not within 0.1m of each other, so a successive iteration must be carried out. Within the computer program designed for carrying out the iterative process, distinct increments are established and the process is terminated when the tolerance requirement is met. In this example, the tolerance requirement was satisfied when 'h' was set at 4.55m (14'-10"). The calculated value of 'h' was 4.647, which is within 0.1m of the trial value.

At the point where the tolerance criterion is met, the lower of the trial value and the calculated value of 'h' is selected as the maximum allowable height. In Lethbridge, therefore, the maximum allowable height for an exterior loadbearing wall of 2x6 SPF (#1 or #2) at 16" o.c. is 14'-10". In terms of the tables developed by this work, 14'-10" is the data point of Table 3A, High Wind load, Low Snow load, 15'-0" roof load tributary (refer to Part 6 of the report).